Atwater (W. O.)

THE CHEMISTRY OF FOODS.

BY

PROF. W. O. ATWATER,

Wesleyan University.

HARTFORD, CONN.:
PRESS OF THE CASE, LOCKWOOD & BRAINARD COMPANY
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Compliments of

W. O. Atwater,

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A pound of lean beef and a quart of milk both contain about the same quantity, say a quarter of a pound, of actually nutritive material. But the pound of beef costs more than the quart of milk and it is worth more as a part of a day's supply of food.

The nutritive materials or nutrients, as we call them, in the lean meat, though the same quantity as in the milk, are different in quality, and of greater nutritive value.

We have here an illustration of a fundamental fact in the economy of foods, namely, that the differences in the values of different foods depend upon both the kinds and the amounts of the nutritive material which they contain. If, then, we will understand the nutritive value of foods, we must know, first of all, what they are composed of. Knowing this, we must next consider what the several food ingredients do in the body; what is the special work which each one of the different nutrients has to perform in building up our bodies and in supplying their wants. When, in addition to all this, we know how much of each class of nutrients our bodies require and our food materials contain we shall be in condition to economize our foods as we do the other necessaries of life.

Twenty-five years ago, indeed, I might say fifteen years ago, but comparatively little was known about these things, and for that matter our knowledge of them is still very far from complete. But, nevertheless, we do know to-day about how much of the different nutritive ingredients, or nutrients, as they are called, our ordinary food materials contain, and we have a tolerably clear conception of the functions of these different ingredients in the

nutrition of our bodies; and finally, a large amount of observation and experiment have told us about what proportions of the several classes of nutrients are required to meet the needs of people in different conditions of life.

LATER RESEARCH IN THE SCIENCE OF FOOD AND NUTRITION.

Among the numerous branches of biological research by no means the least interesting and important is the study of foods and nutrition. Within the past fifteen years especially, a very large amount of scientific labor has been devoted to the investigation of the composition of foods and the function of their ingredients in the animal economy Indeed, very few persons this side of the Atlantic have any just conception of the magnitude of this work and its results. And, though the most important problems are still unsolved, and must, because of their complexity, long remain so, yet enough has been done to give us a tolerably clear insight into the processes by which the food we eat supplies our bodily wants.

The bulk of our best definite knowledge of these matters comes from direct experiments, in which animals are supplied with food of various kinds, and the effects noted. The food, the excrement, solid and liquid, and in some cases the inhaled and exhaled air, are measured, weighed and analyzed. Many trials have been made with domestic animals—horses, oxen, cows, sheep, goats, and swine—with dogs, rabbits, birds, and the like, and a large number also with human beings of both sexes and different ages. In the philosophical planning of the researches, in the ingenuity manifested in devising apparatus, in accuracy, thoroughness, patience, and persistence in the work, as well as in the distinguished genius of many of the workers, chemico-physiological science has assumed the highest rank among the sciences of our time; with the rest it has brought us where we can estimate the nutritive values of foods from their chemical composition, with so near an approach to accuracy that in Germany, where the best research is done, tables, giving in figures the composition and nutritive valuations of foods, have been prepared by eminent chemists and physiologists and are coming into general use.

HOW OUR FOOD SUPPLIES THE WANTS OF OUR BODIES.

Our food supplies the wants of our bodies in four ways:

Food Furnishes,

1. The material of which the body is made.
2. The material to repair the wastes of the body.

Food is Consumed in the Body to,

3. Produce heat to keep it warm.
4. Produce muscular and intellectual strength for work.

To understand how food does its work in the nourishment of the body we must understand what our foods and our bodies are composed of, *i. e.*, their chemical composition.

COMPOSITION OF THE HUMAN BODY—CHEMICAL ELEMENTS.

The chemical compounds of which our bodies are made up are shown by chemical analysis to consist, mainly, of thirteen elements.

Five of these chemical elements are, when uncombined (*i. e.*, each by itself and not united to any other element), gases. They are called :

1. *Oxygen,*	2. *Hydrogen,*	3. *Nitrogen,*
4. *Chlorine,*	5. *Fluorine.*	

The other eight are solid substances. Of these, three are non-metals:

6. *Carbon,*	7. *Phosphorus,*	8. *Sulphur.*

The remaining five are metals:

9. *Iron,*	10. *Calcium,*	11. *Magnesium,*
12. *Potassium,*	13. *Sodium.*	

Besides the above thirteen elements, minute quantities of a few others, as silicon, manganese, and copper are found in the body.

The composition of the bodies of different persons varies greatly with age, size, fatness, etc. No complete chemical analysis of a human body has ever been made, but anatomists have dissected bodies and weighed the different organs, and chemists have made more or less complete analyses of the organs, so that it is possible to make at least a rough estimate of the amounts of the different compounds and elements which a body would contain.

The amounts of the several elements in the body of an average healthy man, five feet eight inches high, and weighing 154 pounds,

may be roughly estimated to be, in pounds and hundredths of a pound, somewhat as follows:

Weights of Chemical Elements in the Body of a Man weighing 154 *pounds.*

Oxygen,	97.20	pounds.
Carbon,	31.10	"
Hydrogen,	15.20	"
Nitrogen,	3.80	"
Calcium,	3.80	"
Phosphorus,	1.75	"
Chlorine,	.25	"
Fluorine,	.22	"
Sulphur,	.22	"
Potassium,	.18	"
Sodium,	.16	"
Magnesium,	.11	"
Iron,	.01	"
Total,	154.00	"

CHEMICAL COMPOUNDS IN THE HUMAN BODY.

These thirteen elements do not exist by themselves in the body, but are combined in a great variety of compounds of which chemists have discovered more than a hundred in the bodies of man and other animals. To enumerate all these here, would of course be quite out of place. It will be very proper, and much more to our purpose, to regard them as belonging to three groups:

A. *Water.*

B. *Organic Compounds.*

C. *Mineral Compounds.*

About water we need here say very little. Of the mineral compounds, one of the most important is the phosphate of lime which makes the basis of bone. Phosphates, sulphates, and chlorides of potassium and sodium, and other mineral salts likewise, occur in our bodies and are essential not only to health, but even to life itself. But in studying food from the standpoint of its nutritive value, that is value for supplying bodily wants, we have to do, chiefly, with the organic compounds. These we may roughly divide into three principal classes, and this classification will do for the organic compounds of both our food and our bodies.

I. *Protein Compounds*, otherwise known as albuminoids, flesh formers, or "flesh substance."

II. *Fats.*

III. *Carbohydrates.*

This division answers very well so long as we are only making approximate estimates of the nutritive values of our foods, but when we study foods very accurately, and more especially when we come to the chemistry of the body, we find compounds which cannot very well be placed in either of these classes. Fortunately for our purpose, however, the proportion of these latter compounds in our foods and in our bodies is very small. Chemists have various ways of grouping the compounds that are found in the human body. The following classification is, perhaps, as good for our purpose as any.

Classification of Compounds in the Body.

Protein Compounds consist mainly of *Carbon,* *Oxygen,* *Hydrogen,* and *Nitrogen.*	*Albuminoids* or *Proteids.*	Albumen of blood and milk. Fibrin of blood. Myosin and Syntonin of Muscle, sometimes called Muscle Fibrin, etc., etc., etc.	
	Gelatinoids,	Ossein of Bone, Gristle, Collagen of Tendons, etc., etc., etc.	Which yield Gelatin.
	Haemoglobin, the red coloring matter of blood.		
Fats consist mainly of *Carbon,* *Oxygen,* and *Hydrogen.*	"*Neutral Fats.*"	Stearin. Olein. Palmitin. etc., etc.	These make the bulk of the fat of the body.
	Nitrogenous and *Phosphorized Fats.*	Protagon, Lecithin, Cerebrin, etc., etc.	These are found chiefly in the brain, spinal cord, nerves, etc. They contain a little nitrogen and phosphorus.
Carbohydrates, etc., consist of *Carbon,* *Oxygen,* *Hydrogen.*	*Glycogen* or "Liver sugar." *Inosite* or "Muscle sugar." *Milk Sugar.* (*Cholesterin,*) etc., etc.		

We have not as yet sufficiently accurate analyses to tell in just what proportions these compounds occur in the body. Very probably the body of an average, healthy man, weighing 154 pounds, would contain something like the following quantities:

Weights of Compounds in Body.

Water,	95.0 pounds.
Protein,	23.5 "
Fats,	24.5 "
Carbohydrates, etc.,	0.2 "
Mineral Matters,	10.8 "
	154.0 "

Of course I do not mean to say that this is an exact statement of the amounts of these compounds in the body of any given man or of an ideal man. These figures are simply an attempt to show, in a general way, in about what proportions the compounds probably occur.

Such then is the composition of the body. These elements and compounds must come from the food. It is the food that furnishes the material of which the growing body of the child is built up, and as our tissues are being continually consumed by work, and thought, and worry, it is by food that they are restored, and finally it is our food that supplies the fuel by whose consumption the heat and strength of the body are maintained. Viewed from the standpoint of their uses in the nutrition of man, the constituents of ordinary foods may be succinctly classified as follows:

1. *Edible Substance*, e. g., the flesh of meats and fish, the shell contents of oysters, wheat flour.

3. *Refuse*, e. g., bones of meat and fish, the shells of oysters, bran of wheat.

The edible substance consists of

1. *Water.*
2. *Nutritive Substance or Nutrients.*

Of the meat my butcher sends me, the fish I find in the market, and the other food upon my table, only a part serves to fulfill these purposes. The bone of my roast beef I do not use for food at all, and that of shad is worse than useless, because of the bother it makes me to get rid of it; it is only the edible portion that is of actual value to me as food, the rest being merely refuse. And when we come to consider the edible portion, the meat freed from bone and gristle, the flesh of the fish, or the flour as it is baked in bread, we find that these consist largely of water. And although water is indispensable, that in the meat or the potatoes on my table is of no more value for the support of my body than the same amount in milk, or in the glass of water by my plate.

Leaving out of account, then, the refuse, and the water, we have the nutritive materials, or, as we may call them, the nutrients of our foods. Speaking as chemists, and physiologists, we may say that our food supplies, besides mineral substances and water, three principal classes of nutritive ingredients or nutrients, viz., albuminoids, carbohydrates, and fats; and that these are transformed into the tissues and fluids of the body, muscle and fat, blood and bone, and are consumed to produce heat and force.

Let me speak in a little more detail of the compounds of which our foods are composed:

Protein, so-called, "flesh-formers," or, "flesh substance."—The terms protein, proteids, and albuminoids, are applied somewhat indiscriminately, in ordinary usage, to several or all of certain classes of compounds characterized by containing carbon, oxygen, hydrogen, and with them, nitrogen. The most important are the proteids, or albuminoids, of which albumen, the white of egg, fibrin of blood, casein of milk, myosin, the basis of muscle, and gluten of wheat, are examples. Allied to these, but occurring in smaller proportions in animal tissues and foods, are the gelatinoids, the nitrogenous compounds that make the basis of connective and other tissues. Gelatin, whence the name gelatinoid (gelatin-like), is derived from some of these tissues, and may be taken as a type of the compound of this class. As these constituents are of similar constitution, and have similar, or nearly similar uses in nutrition, it is customary to group them together as protein. What we should especially bear in mind, then, is that protein is a term applied to the nitrogenous constituents of our foods, and we shall see these are, in general, the most important, as they are most costly, of the nutrients.

The muscular tissues of animals, and hence, the lean portions of meat, fish, etc., contain small quantities of so called nitrogenous extractives—creatin, carnin, etc., which are the chief constituents of meat extract. These contribute materially to the flavor, and somewhat to the nutritive effect of the foods containing them. They are not usually deemed of sufficient importance, however, to be grouped as a distinct class in tabular statements of the composition of foods.

Fats.—We have familiar examples of these in the fat of meat (tallow, lard), in the fat of milk, which makes butter, and in olive, cotton-seed, and other animal and vegetable oils. The fats consist

of carbon, oxygen, and hydrogen, and contain no nitrogen. In nutritive value, as in cost, they rank next to the protein compounds. For some of the nutritive functions, indeed, the fats equal or exceed protein in importance.

Carbohydrates.—Starch, cellulose (woody fiber), sugar, and inosite ("muscle sugar"), and other similar substances, are called carbohydrates. Like the fats, they consist of carbon, oxygen, and hydrogen; but they have less carbon and hydrogen, and more oxygen than the fats.

Mineral Matters, or Ash.—When vegetable or animal matters are burned, more or less incombustible material remains as ash. The ingredients which make the ash are called mineral matters, or, sometimes, salts. They are, for the most part, compounds of the elements, potassium, sodium, calcium, and iron, with chlorine, sulphuric acid, and phosphoric acid. Sodium, combined with chlorine, forms sodium chloride, common salt. Calcium, with phosphoric acid, forms calcium phosphate, or phosphate of lime, the mineral basis of bones.

Our bodies, as I have already said, contain scores of compounds, many of which cannot be included in either of the above four classes. But the bulk of the compounds, exclusive of water, in the bodies of animals, as well as those in the food by which they are nourished, may be classed with either protein, fats, carbohydrates, or mineral matters.

Animal foods, as meats, fish, etc., contain but little of carbohydrates, their chief nutrients being protein and fats. Milk, however, and some shell-fish, as oysters, scallops, etc., contain more or less of carbohydrates. Vegetable foods, as wheat, potatoes, etc., contain less protein, and consist largely of starch, sugar, cellulose, and other carbohydrates, though nearly all contain more or less of fats.

HOW THE NUTRITIVE INGREDIENTS OF THE FOOD NOURISH THE BODY.

These different nutrients, as we have seen, have different offices in nourishing the body, in building up its tissues, repairing its wastes, and serving as fuel to produce animal heat, and muscular and intellectual energy. Just what is done by each class, exactly how they are transformed and used in the body, is not yet fully known. Still, we have, to day, a tolerably fair idea of the principal parts played by each class of nutrients.

Suppose that I have, for breakfast, beef steak, bread and butter, and potatoes. The beef supplies me with considerable protein (in the lean meat) and fat. The butter is nearly all fat. The bread contains a little protein and fat, and the potatoes the same ingredients, but in still smaller proportions, the principal nutrients of both being starch, or carbohydrate.

A small part of the food passes through the body, undigested, and constitutes the excretion of the intestines. The larger portion is digested, taken into the blood, and distributed through the body, where it does its work, is consumed, and finally given off as water, and carbonic acid, by the lungs and skin, and as water, urea, etc., by the kidneys. So, then, the bulk of the protein, fats, and carbohydrates of my breakfast, are digested, and, in the course of the day, the larger part of this digested material finds its way into my blood, and is distributed through my body.

Part of the protein of the food serves to repair my muscles, tendons, skin, and other organs, that are being worn out by constant use. The rest is consumed, sooner or later,—no one knows exactly when, where, or how. Part is probably transformed into fat, and stored as fat in my body, and thus replaces fat that is consumed to keep me warm these cold days and to give my muscles strength for the work they have to do. And probably a part of the protein is changed into glycogen, a carbohydrate which occurs in the liver.

Part of the fat of the meat and bread is stored as fat in my body, and part is burned, yielding heat to keep me warm, and muscular energy as well. The chief use of the carbohydrates, the starch and sugar, of the bread and potatoes seems to be to serve for fuel though they are transformed into fats also. It is a matter of common experience that many people are made corpulent by eating sugar and starchy foods, and grow lean when they avoid them.

THE FUNCTIONS OF THE NUTRIENTS.

According to views formerly held and frequently met with still, the protein compounds were regarded as the "flesh-formers" and the sources of muscular energy, while the carbohydrates and fat were looked upon as "fat-formers" and "heat-producers." A vast deal of painstaking research, however, has shown that these distinctions were not correctly drawn. The albuminoids are flesh-formers, it is true; indeed, according to the nearly unanimous testi-

mony of the most trustworthy experiments, flesh, *i. e.*, muscular and other nitrogenous tissue, is made from the nitrogenous constituents of the food exclusively. But the balance of testimony is decidedly against the production of muscular energy exclusively, or mainly, by nitrogenous compounds. Each of the three groups of nutrients probably shares, directly or indirectly, in the production of muscular force. So, too, it appears that the combustion which produces animal heat is not confined to the carbohydrates and fats, but the protein compounds, or the products of their decomposition, are also used for this purpose.

Again, the production of fat in the body was formerly ascribed to the fats and carbohydrates alone. On the other hand, some physiologists maintain that the carbohydrates cannot be transformed into fats, and that a very large part of the fat of the body is formed from the disintegration of the albuminoids. The weight of evidence to-day is decidedly in favor of the assumption that all three of the great classes of nutrients in our food—the albuminoids, the carbohydrates, and the fats—are transformed into fat, and that the fat thus formed is consumed, either before or after being stored as body fat.

It appears, then, that protein is the most important constituent of our food, because, while it performs the functions of each of the other two chief nutrients in being transformed into fat and being consumed for fuel, it has a most weighty office of its own in forming the basis of the blood, and in building up the muscular and other nitrogenous tissues, an office which no other nutrient can perform at all. And, as we shall see further, in examining the pecuniary cost, protein is the dearest as well as the most important of the ingredients of food.

Next in physiological importance to protein come the fats. They lack the nitrogen of the protein, and cannot do its work in forming nitrogenous tissue, in making blood, muscle, etc. But they are very rich in carbon and hydrogen, more so than either protein or carbohydrates, and hence they have a very high value for fuel to supply heat and probably muscular force. And in pecuniary cost as well as in physiological importance they rank between protein and carbohydrates.

The carbohydrates stand lowest in the scale of physiological importance and are pecuniarily the least expensive. Nevertheless it would be wrong to class the carbohydrates of food as, on the

whole, of minor importance. They have a most important use in taking the place of protein and fats and protecting them from being consumed, just as the fats replace and thus save the protein. The materials used for food by man contain, taken altogether, more carbohydrates than fats or protein. The carbohydrates have their normal place in our food and we could not dispense with them. They are of inferior value to the protein and fats, and in the sense that there is much of the work of food in the body which they cannot do as well as the protein and fats, and much more which they cannot do at all. But they do work which the scarcer and dearer protein and fats would otherwise have to do, and, furthermore, they occur in such large proportions, especially in vegetable materials which make the large part of the food of man, that their actual importance is very great.

One of the interesting matters connected with the use of food in the nutrition of our bodies, is the balance of income and expenditure. To discuss this subject at length, however, would require more time than I ought to take here, so I will endeavor to condense some of the principal facts into a brief statement, as follows:

DAILY INCOME AND EXPENDITURE OF THE HUMAN BODY.

The body receives food, drink, and oxygen, which constitute its income. Part of the material is transformed into flesh, fat, bone, and other tissues of the body. The rest, together with the tissues worn out by use, is transformed into urea, carbonic acid, water, etc. These latter products are given off from the body, and constitute its out-go or expenditure.

Daily Income.—From extended observation and experiments, it has been estimated that an average man, doing moderate work, requires, in order to keep his body well nourished, the equivalent of the following nutritive substances ("nutrients") and water:

Nutrients and Water in Food for a Day.

Protein, 4.2 ounces; fats, 2.0 ounces; carbohydrates, 17.6 ounces; mineral matters, 0.8 ounces; water in food and drink, 11.4 ounces. Total, 96.0 ounces=6 pounds.

Food Rations for a Day.

These substances could be supplied in various food mixtures. The following food materials, for instance, would contain them, and hence suffice for a day's nourishment:

Beefsteak, lean and free from bone, 8 ounces; bread, 20 oz.; potatoes, 30 oz.; butter, 1 oz.; water, 37 oz. Total, 6 pounds.

With the above nutrients about 30 ounces of oxygen would be needed during the twenty-four hours. This is supplied by the air inhaled through the lungs. The foods, drinks, and oxygen thus taken into the body constitute its income.

Daily Expenditure.—A small part of the food passes through the body undigested, and excreted by the intestines. The larger part is digested, taken into the blood, and distributed through the body, where a portion is used to build up and repair the muscles, fat, bone, and other tissues, which are being constantly worn out by use. The remainder unites with the inhaled oxygen, produces heat to keep the body warm and force, strength for work, and is, at the same time, changed into urea, carbonic acid, and water. The worn out portions of the tissues are changed into the same substances. The urea is given off by the kidneys, the carbonic acid by the lungs and skin, and the water by the kidneys, lungs, and skin. So, since the tissues are made up of the food, practically all of the digested protein, fats, and carbohydrates leave the body finally as urea, carbonic acid, and water.

Materials Produced from a Day's Rations.

The day's rations above would yield: Urea, 1.2 oz.; carbonic acid, 38.8 oz.; water found in body, 12.7 oz.; from food and drink, 71.4 oz.; total, 84.1 oz. Mineral matters (digested), 0.7 oz.; undigested matters, 1.4 oz.

These materials make up the expenditure of the body. The daily balance will thus be:

INCOME.			EXPENDITURE.		
Protein,	4.2	ounces.	Urea,	1.2	ounces
Fats,	2.0	"	Carbonic acid,	38.8	"
Carbohydrates,	17.6	"	Water,	84.1	"
Mineral matters,	0.8	"	Mineral matters (digested),	0.7	"
Water of food and drink,	71.4	"	Undigested matters,	1.4	"
Oxygen,	30.2	"			
Total,	126.2	"	Total,	126.2	"

AMOUNTS OF NUTRIENTS REQUIRED FOR A DAY'S RATIONS.

Numerous attempts have been made to determine how much of each of the three classes of nutrients, protein, fats, and carbohy-

drates, is needed for a day's food for an individual, an adult or a child, at work or at rest. We know, in general, a man when hard at work requires more, because more is consumed in his body than the same man would when doing no work. But different men have different requirements, due to individual peculiarities, so that the best we can do is to take an average amount as expressing the need of an average man. By comparing the amounts of carbon, oxygen, hydrogen, and nitrogen, actually found by experiments to be consumed by different individuals, and also noting the amount and composition of the food of different people, estimates have been made of the quantities of the several nutrients required by individuals of different classes under various conditions. Professor von Voit, of the University of Munich, for instance, who has made more extensive researches upon this subject, perhaps, than any one else, computes that a fair daily ration for a laboring man of average weight, at moderate work, would need to supply 4.2 ounces of protein, 2 ounces of fats, and 17.6 ounces of carbohydrates. Of course he may get on with less of either one, provided he has more of the others. But there is a minimum below which he cannot go without injury, and especially he must not have too little protein. He may have more protein and less carbohydrates or fats with no great harm, but with too little protein he will suffer, no matter how much carbohydrates his food may furnish.

If I have dwelt at some length upon this matter of the nutrients of foods and the ways they are used in our bodies, it is because it is extremely important to a proper understanding of our subject. And perhaps I can do no better than to recapitulate what I have said in the following tabular form.

RECAPITULATION OF PRINCIPAL NUTRIENTS OF FOOD.

Protein.
- *Albuminoids or Proteids—E. g.*, albumen of egg, myosin of muscle (lean of meat), casein of milk, gluten of wheat.
- *Gelatinoids: e. g.*, ossem of bone, collagen of tendons (which boiled yield gelatin).

Fats: e. g., fats of meat, butter, olive oil, oil of maize and wheat.

Carbohydrates: e. g., starch, sugar, cellulose (woody fiber).

Mineral Matters or Ash: e. g., calcium, potassium and sodium, phosphates and chlorides.

MEAN PERCENTAGE COMPOSITION.

	Protein compounds. Per cent.	*Fats.* Per cent.	*Carbohydrates.* Per cent.
Carbon, . . .	53.5	76.5	44.0
Oxygen, . . .	22.5	11.5	50.0
Hydrogen, . . .	7.0	12.0	6.0
Nitrogen, . . .	16.0	....	....
Sulphur, . . .	1.0	....	....
	100.0	100.0	100.0

FUNCTIONS OF NUTRIENTS.

I. e., Ways in which the nutrients are used in the body.

The Protein of food.
- forms the (nitrogenous) basis of blood, muscle, connective tissue, etc.
- is transformed into fats and carbohydrates.
- is consumed for fuel.

The Fats of food.
- are stored as fat.
- are consumed for fuel.

The Carbohydrates of food.
- are transformed into fat.
- are consumed for fuel.

AMOUNTS OF NUTRIENTS REQUIRED IN A DAY'S FOOD.

Minimum daily ration for laboring man at ordinary work.

Protein.	*Fats.*	*Carbohydrates.*
118 grams (4.2 oz.).	56 grams (2 oz.)	500 grams (17.6 oz.).

The same experimental research which has revealed to us the ways in which our food supplies our bodily wants, has shown us how to estimate the relative nutritive values of different foods from their chemical composition. The estimates are only approximate, because the nutritive effects are influenced by various conditions, some of which research has not definitely explained, while others vary with the nature of the food or the user, so that the value of a given food in a given case may vary from the standard set by the analysis. These sources of uncertainty are nevertheless so narrowed down by late investigation, and the errors confined within such limits, that by intelligent use of the facts at our disposal we may judge very closely from the chemical composition of a food what is its value as compared with others of the same class, at any rate for our nourishment.

CHEMICAL ANALYSIS OF FOODS.

Let us, then, notice what chemical analysis has to say of the amounts of the different nutrients in some of our ordinary foods. The tables beyond give results of analyses, the most of which are selected from a much larger number, performed in the chemical laboratory of Wesleyan University, at the instance of the Smithsonian Institution, for the Food Collection of the United States National Museum.

The details will perhaps be best explained by an example. The flesh, or edible portion of a specimen of beef sirloin, of medium fatness, was analysed and found to contain, approximately: water, 60 per cent.; protein, 19 per cent.; fats, 20 per cent.; mineral matters, 1 per cent. But when we buy our sirloin steak or roast, by the pound, as we ordinarily do, we get not only the flesh, the edible substance, but with it more or less bone, sinew, and other refuse matter. This specimen contained about one-fourth, or twenty five per cent. bone, and only three-fourths, seventy-five per cent., of flesh. If, then, we are to consider the composition of the meat as we buy it, we must take the refuse matters into account. The proportions of the several ingredients in both the edible portion, and the whole piece above referred to, are shown in the following table.

	In flesh, edible portion.	In meat as bought, including refuse.
	Per cent.	Per cent.
Refuse, bones, etc.,	None.	25
Water,	60	45
Protein,	19	14¼
Fat,	20	15
Mineral matters,	1	0¾
Total,	100	100

This very imperfect analysis may be stated in the following form, as is done in the tables beyond: *

* The tables contain also columns for carbohydrates, etc., which occur in milk and in some shell-fish, but are not found in ordinary meats in sufficient amount to warrant their insertion in such tables as these.

CONSTITUENTS OF SAMPLE OF BEEF, SIRLOIN.

FOOD-MATERIAL.	IN EDIBLE PORTION— i. e., flesh freed from bone and other refuse.					IN MEAT AS PURCHASED— including both edible portion and refuse.					
			NUTRIENTS.				EDIBLE PORTION.				
									NUTRIENTS.		
	Water.	Nutrients.	Protein.	Fats.	Mineral matters.	Refuse: bones, etc.	Water.	Nutrients.	Protein.	Fats.	Mineral matters.
Beef, sirloin, med. fatness, ...	Pr. ct. 60	Pr. ct. 40	Pr. ct. 19	Pr. ct. 20	Pr. ct. 1	Pr. ct. 25	Pr. ct. 45	Pr. ct. 30	Pr. ct. 14.3	Pr. ct. 15	Pr. ct. 0.7

Tables I and II, herewith, give the composition of a number of animal foods, mostly from late American analyses. It is only a short time since analyses of American meats, fish, etc., have been undertaken in any considerable number, and those as yet accomplished are far from sufficient for a complete survey of the subject. Indeed, the work already done can be regarded only as a beginning. Still, the figures will give a tolerably fair idea of the composition of the articles named.

TABLE I.

COMPOSITION OF ANIMAL FOODS.

EDIBLE PORTION—Flesh, etc., Freed from Bone, Shells, and other Refuse.

KINDS OF FOOD MATERIALS. (*Italics* indicate European Analyses, the rest are American.)	Water.	Nutrients.	NUTRIENTS. Protein (Albuminoids).	Fats.	Carbohydrates, etc.	Mineral Matters.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
MEATS—Fresh.							
Beef, side, well fattened,	54.6	45.4	17.9	26.5	....	1.0	
Beef, lean, nearly freed from fat,	76.0	24.0	21.8	0.9	....	1.3	
Beef, round, rather lean (1),	66.7	33.3	23.0	9.0	....	1.3	
Beef, sirloin, rather fat (1),	60.0	40.0	19.0	20.0	....	1.0	
Beef, flank, very fat (1),	27.3	72.7	12.4	59.6	....	0.7	
Beef, liver,	69.5	30.5	20.1	5.4	3.5	1.5	
Beef, tongue,	63.8	36.2	17.1	18.1	....	1 0	
Beef, heart,	56.8	43.2	15.8	26.3	....	1.1	
Veal, lean,	78.8	21.2	19.9	0.8	....	(0.5)	
Veal, rather fat,	72.3	27.7	18.9	7.5	....	(1.3)	
Mutton, side, well fattened,	53.6	46.4	16.5	29.0	....	0.9	
Mutton, leg (1),	61.9	38.1	18.2	19.0	....	0.9	
Mutton, shoulder (1),	58.6	41.4	18.0	22.4	....	1.0	
Mutton, loin (chops),	49.3	50.7	14.9	35.1	....	0.7	
MEATS PREPARED.							
Dried beef,	59.5	40.5	29.2	4.5	....	6.8	
Corned beef, rather lean,	58.1	41.9	13.3	26.6	....	2.0	
Smoked ham,	41.5	58.5	16.7	39.1	....	2.7	
Pork, bacon, salted,	10.0	90.0	3.0	80.5	....	6.5	
FOWL.							
Chicken, rather lean,	72.2	27.8	24.5	1.9	....	1.4	
Turkey, medium fatness,	66.2	33.8	23.8	8.7	....	1.3	
Goose, fat,	38.0	62.0	15.9	45.6	....	0.5	
DIARY PRODUCTS, EGGS, Etc.							
Cow's milk,	87.4	12.6	3.4	3.8	4.8	0.7	
Cow's milk, skimmed,	90.7	9.3	3.1	0.7	4.8	0.7	
Cow's milk, buttermilk,	90.3	9.7	4.1	0.9	4.0	0.7	
Cow's milk, whey,	93.2	6.8	0.9	0.2	5.0	0.7	
Cheese, whole milk,	31.2	68.8	27.1	35.4	2.4	3.9	
Cheese, skimmed milk,	41.3	58.7	38.3	6.8	9.0	4.6	
Butter,	9.0	91.0	1.0	87.5	0.5	2.0	
Hen's Eggs,	73.7	26.3	12.5	12.1	0 6	1.1	
FISH, Etc.							
Flounder, whole,	84.2	15.8	13.8	0.7	....	1.3	
Haddock, dressed,	81.7	18.3	16.8	0.3	....	1.2	
Bluefish, dressed,	78.5	21.5	19.0	1.2	....	1.3	
Cod, dressed,	82.6	17.4	15.8	0.4	....	1.2	
Whitefish, whole,	69.8	30.2	22.1	6.5	....	1.6	
Shad, whole,	70.6	29.4	18.5	9.5	....	1.4	
Mackerel, average, whole,	73 4	26.6	18.2	7.1	....	1.3	
							SALT.
Salt Cod,	53.6	25.8	21.4	0.3	....	4.1	20.6
Smoked Herring,	34.5	53.8	36.4	15.8	....	1.6	11.7
Salt Mackerel,	42.2	47.2	22.0	22.6	....	2.6	10.6
Oysters, average,	87.3	12.7	6.0	1.2	3.5	2.0	
Scallops, edible portion,	80.3	19.7	14.7	0.2	3.4	1.4	

(1) Portions of the side of which analysis is given above.

TABLE II.

COMPOSITION OF ANIMAL FOODS.

SPECIMENS AS PURCHASED IN THE MARKETS.

(Including both Edible Portions and Refuse.)

KINDS OF FOOD MATERIALS. (*Italics* indicate European analyses, the rest are American.)	Refuse:— Bones, Skins, Shells, Etc.	Salt.	Edible Portion. Water.	Edible Portion. Nutrients.	Nutrients. Protein (Albuminoids).	Nutrients. Fats.	Nutrients. Carbohydrates, Etc.	Nutrients. Mineral Matters.
	Per cent.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
MEATS—Fresh.								
Beef, side, well fattened,	19.7		43.8	36.5	14.4	21.3	......	0.8
Beef, lean, nearly freed from fat,	....		76.0	24.0	21.8	0.9	......	1.3
Beef, round, rather lean (1),	10.0		60.0	30.0	20.7	8.1	......	1.2
Beef, sirloin, rather fat (1),	25.0		45.0	30.0	14.3	15.0	......	0.7
Beef, flank, very fat (1),	12.5		23.9	63.6	10.8	52.2	......	0.6
Beef, liver,	....		69.5	30.5	20.1	5.4	3.5	1.5
Beef, tongue,	15.3		54.0	30.7	14.5	15.3	......	0.9
Beef, heart,	6.0		53.4	40.6	14.9	24.8	......	0.9
Mutton, side well fattened,	20.0		42.9	37.1	13.2	23.2	......	0.7
Mutton, leg (1),	18.4		40.2	41.4	12.2	28.6	......	0.6
Mutton, shoulder (1),	16.9		48.7	34.4	15.0	18.6	......	0.8
Mutton, loin, chops (1),	16.3		41.3	42.4	12.5	29.3	......	0.6
MEATS—Prepared.								
Dried beef,	6.5		55.5	38.0	27.4	4.2	......	6.4
Corned beef, rather lean,	6.2		54.5	39.3	12.5	24.9	......	1.9
Smoked ham,	12.5		36.3	51.2	14.6	34.2	......	2.4
Pork, bacon, salted,	5.0		9.5	85.5	2.8	76.5	......	6.2
FOWL.								
Chicken, rather lean,	41.6		42.2	16.2	14.3	1.1	......	0.8
Turkey, medium fatness,	35.4		42.8	21.8	15.4	5.6	......	0.8
DAIRY PRODUCTS, EGGS, Etc.								
Cow's milk,	....		87.4	12.6	3.4	3.7	4.8	0.7
Cow's milk, skimmed	....		90.7	9.3	3.1	0.7	4.8	0.7
Cow's milk, buttermilk,	....		90.3	9.7	4.1	0.9	4.0	0.7
Cow's milk, whey,	....		93.2	6.8	0.9	0.2	5.0	0.7
Cheese, whole milk,	....		31.2	68.8	27.1	35.4	2.4	3.9
Cheese, skimmed milk,	....		41.3	58.7	38.3	6.8	9.0	4.6
Butter,	....		9.0	91.0	1.0	87.5	0.5	2.0
Hen's eggs,	11.0		65.6	23.4	11.1	10.8	0.5	1.0
FISH, Etc.								
Flounder, whole,	66.8		27.2	6.0	5.2	0.3	......	0.5
Haddock, dressed,	51.0		40.0	9.0	8.3	0.1	......	0.6
Blue-fish, dressed,	48.6		40.3	11.1	9.8	0.6	......	0.7
Cod, dressed,	29.9		57.9	12.2	11.0	0.3	......	0.9
Whitefish, whole,	53.5		32.5	14.0	10.3	3.0	......	0.7
Shad, whole,	50.1		35.2	14.7	9.3	4.7	......	0.7
Mackerel, average, whole,	44.6		40.7	14.7	10.1	3.9	......	0.7
Salt Cod,	24.9	15.4	40.3	19.4	16.0	0.4	......	3.0
Smoked Herring,	44.4	6.5	19.2	29.9	20.2	8.8	......	0.9
Salt Mackerel,	22.9	8.2	32.5	36.4	17.0	17.4	......	2.0
Oysters, average,	82.3		15.4	2.3	1.0	0.2	0.6	0.5
Scollops; edible portion,	....		80.3	19.7	14.6	0.2	3.6	1.3

(1) Portions of the side of which analysis is given.

The figures of this table, with the exception of a few from European sources and indicated by italics, are selected from the results of the investigation referred to above, as conducted under the auspices of the Smithsonian Institution and the United States Fish Commission. The specimens of meats were purchased from a dealer in Middletown, Conn., and said by him to be "fair average samples of the better kinds of meats." A side of beef, freshly brought in winter from Chicago, and said to be a fair specimen of the best quality of "Chicago beef," was cut into about twenty-five pieces in the ordinary way. From each a sample fairly representing the whole cut was taken and analyzed. Thus the composition of each piece and of the whole side was learned. The composition of one of the leanest portions, the round, a moderately fat piece, sirloin, a very fat portion, flank, and of the whole side, together with a tongue, liver, and heart from another animal, are given in the table. The samples of a side of mutton and of parts of the same side were obtained and analyzed in like manner, as were those of the other meats and fowls. The specimens of cheese were from Washington market, New York, the analyses in the table representing averages of several samples. The butter was from a Vermont dairy. Some of the specimens of fish were purchased in Middletown, the most, however, were furnished gratuitously from Fulton market, New York, by Mr. E. G. Blackford, Fish Commissioner of the State of New York, who also contributed to the pecuniary expense of the investigation, as did likewise Mr. A. R. Crittenden of Middletown. A considerable number of the specimens whose analyses are given in this table, and in the tables beyond, were furnished by Mr. F. B. Thurber of New York, who also contributed a considerable sum toward defraying the cost of the research, as did also Hon. J. W. Alsop, M.D., of Middletown, Conn. It may be added that the figures in Table I (aside from European sources) are selected from the results of nearly three hundred analyses of American food materials, of which some two hundred are of fish and invertebrates. The analyses of fish, being more numerous, give more satisfactory figures and averages than those of meats, etc. It may not be out of place to give some of the analyses of fish, shell-fish, etc., by themselves as is done in Tables III and IV.

TABLE III.

COMPOSITION OF FOOD FISHES AND INVERTEBRATES.

FLESH—EDIBLE PORTION.

(Freed from Bone, Shells, and other Refuse Matters.)

Specimens of flesh of Fish and of edible portion (flesh and liquids), of Oysters, etc. were found to contain water and nutritive substance, as below. The figures represent parts in 100 by weight. Protein + Fats + Carbohydrates, etc. + Mineral Matters = Nutrients. Nutrients + Water = 100.

KINDS OF FOOD FISHES AND INVERTEBRATES.	Salt	Water.	Nutrients.	NUTRIENTS. Protein.	Fats.	Carbohy-drates, etc.	Mineral Matters.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
FRESH FISH.							
Alewife,		73.0	27.0	19.5	6.0	......	1.5
Black Bass,		76.7	23 3	20.4	1.7	......	1.2
Bluefish,		78.5	21.5	19.0	1.2	......	1.3
Cod,		82.6	17.4	15.8	0.4	......	1.2
Eel,		71.6	28.4	18.3	9.1	......	1.0
Lamprey Eel,		71.1	28.9	14.9	13.3	......	0.7
Flounder,		84.2	15.8	13.8	0.7	......	1.3
Haddock,		81.7	18.3	16.8	0.3	......	1.2
Halibut,		75.4	24.6	18.3	5.2	......	1.1
Herring,		69.0	31.0	18.5	11.0	......	1.5
Mackerel, rather lean,		78.7	21.3	18.1	2.2	......	1.0
Mackerel, fat,		64.0	36.0	18.2	16.3	......	1.5
Mackerel, average,		73.4	26.6	18.2	7.1	......	1.3
Yellow Perch,		79.2	20.8	18.7	0.8	......	1.3
Pike Perch,		79.7	20.3	18.4	0.5	......	1.4
Pickerel (Pike),		79.7	20.3	18.6	0.5	......	1.2
Salmon. In season, fat,		61.4	38.6	24.2	13.0	......	1.4
Salmon. "Spent" lean,		79.2	20.8	17.6	2.0	......	1.2
Shad,		70.6	29.4	18.5	9.5	......	1.4
Smelt,		79.2	20.8	17.3	1.8	......	1.7
Brook Trout,		77.7	22.3	19.0	2.1	......	1.2
Salmon Trout,		69.1	30.9	18.3	11.3	......	1.3
Whitefish,		69.8	30.2	22.1	6.5	......	1.6
PREPARED FISH.	Salt per cent.						
Dried Cod. Boned and dried artificially,	2.9	15.2	81.9	74.6	1.9	......	5.4
Salt Cod. Salted and Dried,	20.6	53.6	25.8	21.4	0.3	......	4.1
Salt Mackerel. "No. 1 Mackerel" Salted,	10.6	42.2	47.2	22.6	22.9	......	2.6
Smoked Haddock. Salted, Smoked, and Dried,	2.1	72.6	25 3	23.6	0.2	......	1.5
Smoked Herring. Salted, Smoked, and Dried,	11.7	34.5	53.8	36.4	15.8	......	1.6
Canned Salmon,	1.3	59.9	38.8	19.4	18.0	......	1.4
Canned Fresh Mackerel,	1.9	68.2	29.9	19.9	8.7	......	1.3
Canned Salt Mackerel. "No. 2 Mackerel" Salted,	10.3	43.4	46.3	17.3	26.4	......	2.6
INVERTEBRATES. SHELL FISH, ETC.							
Oysters. Shell contents. Best (1),		83.4	16.6	6.4	1.7	6.5	2.0
Oysters. Shell contents. Inferior (1),		91.4	8.6	4.5	0.6	1.8	1.7
Oysters. Shell contents. Average (1),		87.3	12.7	6.0	1.2	3.5	2.0
Long Clams. Shell contents,		85.9	14.1	8.2	1.0	2.3	2.6
Round Clams. Shell contents,		86.2	13.8	6.6	0.4	4.2	2.6
Mussels. Shell contents,		84.2	15.8	8.7	1.1	4.1	1.9
Scallops. Edible portion (Muscle),		80.3	19.7	14.7	0.2	3.4	1.4
Lobsters. Edible portion,		81.8	18.2	14.5	1.8	0.2	1.7
Crabs. Edible portion,		77.1	22.9	16.6	2.0	1.2	3.1
Cray Fish. Edible portion,		81.2	18.8	16.0	0.5	1.0	1.3
Canned Oysters,		85.2	14.8	7.4	2.1	4.0	1.3
Canned Lobsters,		77.8	22.2	18.0	1.1	0.6	2.5

(1) In respect to quantity of nutrients.

(2) Shell contents as comonly sold, including whole of "solid" and most of liquid portion.

TABLE IV.

COMPOSITION OF FOOD FISHES AND INVERTEBRATES.

SPECIMENS AS FOUND IN THE MARKETS.

Specimens of Fish—whole or dressed—and of Oysters, etc., including or freed from the shell, as ordinarily sold in the New York or Middletown, Conn., markets, were found to contain:

1. Refuse—Bone, Shells, and other Inedible Matters.
2. Edible Portion—Water and Nutritive Substances.
3. Ingredients of Nutritive Substance, Nutrients—Protein, Fats, Carbohydrates, etc., and Mineral Matters in parts in 100 by weight, as below. (Nutrients + Water + Refuse = 100.)

Kinds of Food Fishes and Invertebrates, and Portions Taken for Analysis.	Salt	Refuse. Bone, Skin, Shells, etc.	Edible Portion. Water.	Edible Portion. Nutrients.	Nutrients. Protein.	Nutrients. Fats.	Nutrients. Carbohydrates, etc.	Nutrients. Mineral Matters.
FRESH FISH.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Alewife. Whole,		49.4	36.9	13.7	9.9	3.0	.....	0.8
Black Bass. Whole,		54.8	34.6	10.6	9.2	0.8	.....	0.6
Bluefish. Entrails removed,		48.6	40.3	11.1	9.8	0.6	.....	0.7
Cod. Head and entrails removed,		29.9	57.9	12.2	11.0	0.3	.....	0.9
Eel. Skin, head, and entrails removed,		20.2	57.1	22.7	14.6	7.3	.....	0.8
Lamprey Eel. Whole,		45.8	38.5	15.7	8.1	7.2	.....	0.4
Flounder,		66.8	27.2	6 0	5.2	0.3	.....	0.5
Haddock. Entrails removed,		51.0	40.0	9.0	8.3	0.1	.....	0.6
Halibut. Sections of body,		17 7	62.1	20.2	15.1	4.2	.....	0.9
Herring. Whole,		46.0	37.3	16.7	10.0	5.9	.....	0.8
Mackerel. Rather lean. Whole,		38.3	48.5	13.2	11.2	1.4	.....	0.6
Mackerel. Fat,		33.8	42.4	23.8	12.1	10.7	.....	1.0
Mackerel. Average,		44.6	40.7	14.7	10.1	3.9	.....	0.7
Yellow Perch. Whole,		62.7	30.0	7.3	6.7	0.2	.....	0.4
Pike Perch. Whole,		57.2	34.1	8.7	7.9	0.2	.....	0.6
Pickerel (Pike). Whole,		47.0	42.2	10.8	9.9	0.2	.....	0.7
Salmon. In season, fat. Whole,		38 5	37.6	23.9	15.0	8.0	.....	0 9
Salmon. "Spent" lean. Whole,		46.2	42.6	11.2	9.5	1.0	.....	0.7
Shad. Whole,		50.1	35.2	14.7	9.3	4.7	.....	0.7
Smelt. Whole,		41.9	46.1	12.0	10.0	1.0	.....	1.0
Brook Trout. Whole,		48.1	40.3	11.6	9.9	1.1	.....	0.6
Salmon Trout. Entrails removed,		35.2	45.0	19.8	12.4	6.6	.....	0.8
Whitefish,		53.5	32.5	14.0	10.3	3.0	.....	0 7
PREPARED FISH.	Salt per cent.							
Dried Cod. Boned and dried,	2.9	.....	15.2	81.9	74.6	1.9	.....	5.4
Salt Cod. Salted and dried,	15.4	24.9	40.3	19.4	16 0	0.4	.....	3.0
Salt Mackerel. "No. 1 Mackerel" Salted,	8.2	22.9	32.5	36.4	17.0	17.4	.....	2.0
Smoked Haddock. Salted, Smoked, and Dried,	1.4	32.2	49.2	17.2	16.1	0.1	.....	1.0
Smoked Herring. Salted, Smoked, and Dried,	6.5	44.4	19.2	29.9	20.2	8.8	.....	0.9
Canned Salmon. California (Oregon),	1.3	.....	59.9	38.8	19.4	18.8	.....	1.3
Canned Fresh Mackerel,	1.9	.....	68.2	29.9	19.9	8.7	.....	1.3
Canned Salt Mackerel "No. 2 Mackerel" Salted,	8.3	19.7	34.8	37.2	13.8	21.3	....	2.1
INVERTEBRATES, SHELL FISH, Etc.								
Oysters. In shell. Inferior (1),		88.8	10.2	1.0	0.5	0.1	0.2	0.2
Oysters. In shell. Best (1),		81.4	15 2	3.4	1 5	0.2	1.3	0.4
Oysters. In shell. Average,		82.3	15.4	2.3	1.0	0.2	0.6	0.5
Oysters. "Solids" (2),		.....	87 2	12.8	6.2	1.5	4.1	1.0
Long Clams. In shell,		43.8	48.3	7.9	4.3	0.5	1.3	1.8
Round Clams. In shell,		68.3	27.3	4.4	2 1	0.1	1.3	0.9
Mussels. In shell,		49 3	42.7	8 0	3.9	0.5	2.1	1.5
Scallops. Edible portion (Muscle),		.....	80 3	19.7	14.7	0.2	3.4	1.4
Lobsters. In shell,		60.2	33.0	6.8	5.4	0.5	0.2	0.7
Crabs. In shell,		55.8	34.1	10.1	7 3	0.9	0.5	1.4
Crayfish. In shell,		87.7	10 0	2.3	1.9	0 1	0.1	0.2
Canned Oysters,		.....	85 2	14.8	7.4	2 1	4.0	1.3
Canned Lobsters,		.....	77.7	22 3	18 1	1.1	0.6	2.5

(1) In respect to quantity of nutrients.
(2) Including solid and most of liquid shell contents as commonly sold.

TABLE V.

CONSTITUENTS OF VEGETABLE FOODS AND BEVERAGES.

KINDS OF FOODS AND BEVERAGES.	Water.	Nutrients.				
		Protein (albuminoids).	Fats.	Carbohydrates, etc.	Woody fibre.	Mineral Matters.
FOODS.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Wheat-flour, average, *	11.6	11.1	1.1	75.4	0.2	0.6
Wheat flour, maximum, *	13.5	13.6	2.0	78.5	1.2	1.5
Wheat-flour, minimum, *	8.3	8.6	0.6	68.3	0.1	0.3
Graham-flour (wheat),	13.0	11.7	1.7	69.9	1.9	1.8
Cracked wheat,	10.4	11.9	1.7	74.6		1.4
Rye-flour,	13.1	6.7	0.8	78.3	0.4	0.7
Pearled barley,	11.8	8.4	0.7	77.8	0.3	1.0
Buckwheat flour,	13.5	6.5	1.3	77.3	0.3	1.1
Buckwheat "farina,"	11.2	3.3	0.3	84.7	0.1	0.4
Buckwheat "groats,"	10.6	4.8	0.6	83.1	0.3	0.6
Oatmeal,	7.7	15.1	7.1	67.2	0.9	2.0
Cornmeal,	14.3	8.4	3.5	70.9	1.6	1.3
Hominy,	13.5	8.3	0.4	77.1	0.3	0.4
Rice,	12.4	7.4	0.4	79.2	0.2	0.4
Beans,	13.7	23.2	2.1	53.7	3.7	3.6
Peas,	15.0	22.9	1.8	52.4	5.4	2.5
Potatoes,	75.5	2.0	0.2	20.7	0.8	1.0
Sweet-potatoes,	75.8	1.5	0.4	20.0	1.1	1.2
Turnips,	91.2	1.0	0.2	6.0	0.9	0.7
Carrots,	87.9	1.0	0.2	8.9	1.2	0.8
Cabbage,	90.0	1.9	0.2	4.9	1.8	1.2
Cauliflower,	90.4	2.5	0.4	5.0	0.9	0.8
Melons.	95.2	1.1	0.6	1.4	1.1	0.6
Pumpkins,	90.0	0.7	0.1	7.3	1.3	0.6
Apples,	84.8	0.4	0.0	12.8	1.5	0.5
Pears,	83.0	0.4	0.0	12.0	4.3	0.3
Starch,	15.1	1.2	0.0	83.3	0.0	0.4
Cane-sugar,	2.2	0.3	0.0	96.7	0.0	0.8
Wheat-bread, †	32.7	8.9	1.9	55.5		1.0
Graham-bread,	34.2	9.5	1.4	53 3		1.6
Rye-bread,	30.0	8.4	0.5	59.7		1.4
Soda-crackers,	8.0	10.3	9.4	70.5		1.8
"Boston" crackers,	8.3	10.7	9.9	68.7		2 4
"Oyster" crackers,	3.9	12.3	4.8	76.5		2.5
Oatmeal-crackers,	4.9	10.4	13.7	69.6		1.4
Pilot (bread) crackers,	7.9	12.4	4.4	74.2		1.1
Macaroni,	13.1	9.0	0.3	76.8		0.8
BEVERAGES.			Alcohol.		Free acid.	
Lager-beer,	90.3	0.5	4.0	6.6	......	0.2
Porter and ale,	88.5	0.7	5.2	7.2	......	0.3
Rhenish wine, white,	86.3	....	10.5	2.6	0.4	0.2
Rhenish wine, red,	86.9	.... ..	8.9	3.4	0.5	0.3
French wine, claret,	88.4	....	8.1	2.7	0.6	0.2

* Of forty-nine analyses.
† From flour of about average composition.
The analyses of foods in Roman letters are American, those of foods and beverages in *Italics* are European.

Table V gives analyses of vegetable food materials and beverages. The figures for wheat-flour represent the results of forty-nine analyses of American flours, of which the majority were analyzed under the direction of Prof. Brewer, and the rest collated by him from other sources for the "Report of the United States Census, 1880." The largest and the smallest percentages of each ingredient found in the analyses are given opposite "maximum" and "minimum." The specimens of bread, crackers, etc., were purchased and analyzed at Middletown, Conn., and have probably about the usual composition of such materials.

I have said so much by way of introduction to the tables, that it may be hardly advisable to discuss their contents at much length. Nor will this be necessary, for the figures themselves tell their own stories and very plainly. Only a glance is needed to show, for instance, that fish as found in the markets generally contain more refuse bone, skin, etc., than meats, as is illustrated in Tables I and II. With the larger proportions of both refuse and water, the proportions of nutrients, though variable, are usually much less than meats. Thus a sample of flounder contained sixty-seven per cent. of refuse, twenty-eight of water, and only five per cent. of nutritive substance, while the salmon averaged twenty-three, the salt cod twenty-two, and the salt mackerel thirty-six per cent. of nutrients. The nutrients in meats ranged from thirty per cent. in beef to forty-six in mutton, and eighty-seven and a half in very fat pork (bacon). The canned fish compare very favorably with the meats. It is worth noting, that the nutrients in fresh codfish, dressed, in oysters, edible portion, and in milk, all were nearly the same in amount—about twelve and a half per cent., though differing in kind and proportions.

Vegetable foods have generally less water and more nutrients than animal foods. Ordinary flour, meal, etc., contain from eighty-five to ninety per cent. or more of nutritive material. But the nutritive values are not exactly proportional to the quantity of nutrients, because the vegetable foods contain but little protein and consist mostly of carbohydrates, starch, sugar, cellulose, etc., which are of inferior nutritive value, and because the protein they do contain is less digestible than that of animal foods. Potatoes contain a large amount of water, and extremely little protein or fats.

I wish to call attention to two more things concerning the composition of fish:

1st. The chief difference between the flesh of fish and ordinary meats is, that the fish generally contains less fat and more water. The fat contained in the meats is, in the fish, replaced to a considerable extent, by water. On this account, the flesh of fish has, generally, a lower nutritive value, pound for pound, than ordinary meats. Fish, as we buy them, have the further disadvantage in comparison with meats, that they contain larger percentages of refuse bone, skin, entrails, etc., than meats.

2d. On the other hand, in the flesh of most fish, the nutritive material is nearly all protein. That is to say, fish supply the ingredient of food which is the most important, and as we shall see, the most expensive of all.

There is one difficulty with the tables, namely, that the figures for the analyses apply to either single specimens, or to averages of a number of specimens, and do not show the variations in the composition of the same food-material, which are often quite considerable. Two illustrations of this are given, the mackerel in Table IV, and the wheat flour in Table V. The figures for "maximum and minimum" in the latter show as above indicated, the largest and smallest percentages of each ingredient found in the forty-nine specimens of American wheat flour analyzed. Thus the percentages of water vary from eight and three tenths to thirteen and five tenths, the average being eleven and six tenths per cent., while the protein varies from eight and six tenths to thirteen and six tenths, averaging eleven and one tenth per cent.*

I hope to give elsewhere, at a proper time, more detailed tables of analyses illustrating these differences in detail, though it must be confessed that the number of analysis thus far made are very far from sufficient to show at all completely the variations in the composition of our food materials. Nevertheless, the figures in the tables give a tolerably accurate idea of the composition of the food materials named.

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*Since the above tables were prepared, the results of a large series of analyses of American grain and milling products have been reported by Mr. Clifford Richardson of the United States Agricultural Department. While these are a most important contribution to our knowledge of the subject, the main results do not differ widely from those here given.

DIGESTIBILITY OF FOODS.

The question of the digestibility of foods is a very complex and difficult one, and I have noticed that the men who know most about it, are generally the least ready to make definite and sweeping statements as to the digestibility of this or that kind of food material. One great difficulty is the fact that, what we ordinarily call the digestibility of a food includes several different things, the ease with which it is digested, the time required for digesting it, and the proportions of its several constituents that are digested.

The ease of digestion and the suitableness of a food to the digestive organs of a given person are physiological rather than chemical questions, and, fortunately for myself, do not come within the scope of this lecture. The actual amounts digested are capable of more nearly accurate determination. Indeed, the percentage of the more important constituents of various foods actually digested by domesticated animals of different species, breeds, sexes, and ages, and under varying circumstances, has been a matter of active experimental investigation in the German agricultural experiment stations during the past twenty years. Briefly expressed, the method consists in weighing and analysing both the food consumed and the solid excrement, which latter represents the amount of food undigested, the difference being the amount digested.

Such experiments upon human subjects, however, are rendered much more difficult by the necessity of avoiding complex mixtures of foods, in order that the digestibility of each particular food or food ingredient may be determined with certainty, and the fact that it is not easy to continue to eat the same kind of food long enough for a satisfactory experiment. No matter how palatable a simple food may be to a man at first, it has been found that it will almost certainly become repugnant to him after two or three days. In consequence, the digestive functions are disturbed, and the accuracy of the trial is impaired. In the experiments now in question, it was quite exceptional to find persons, in any walk of life, who could continue to eat large quantities of simple, plain food for tolerably long periods—a fact, by-the-way, which strikingly illustrates and emphasizes the importance of a varied diet in ordinary life.

Notwithstanding the difficulties referred to, a considerable num-

ber of experiments have been carried out, the majority in the physiological laboratory of the University of Munich, Germany. The results of a number of these experiments are concisely set forth in the following table.

PERCENTAGES OF UNDIGESTED MATTERS IN FOOD-MATERIALS.

KIND OF FOOD EATEN.	Percentage of the dry food lost as excrement.	PERCENTAGES OF THE Nitrogen * (Of the foods which go to waste in the excrement.)	PERCENTAGES OF THE Carbohydrates (Of the foods which go to waste in the excrement.)
Lean beef,	5 or 6	2 or 3	....
Fish (haddock),	5 or 6	2 or 3	....
Eggs,	5¼	2½	....
Milk,	8 to 10	7 to 12	....
Milk with cheese,	6 to 11	3 to 5	....
Rice,	4	25	1
Potatoes,	9⅛	32	7½
Fat bacon, with some bread and beef,	8½ to 9¼	12 to 14	2 to 6
White bread (wheat),	3¾ to 5⅓	19 to 26	1 to 1½
Coarse rye-bread (black bread),	15	32	11
Cabbage,	15	18½	15½
Yellow beets,	21	39	18

* Protein.

Thus the men upon whom the experiments were made digested all but 5 or 6 per cent. of the whole dry matter (water free substance) of the lean beef and the fish, and all but 3 per cent. of their protein (nitrogen). Of the water free substance of milk, a somewhat larger proportion passed through the body undigested. The vegetable foods were much less completely digested, the coarse rye bread and the beets, were, in this sense, the least digestible of all.

PECUNIARY ECONOMY OF FOODS.

COMPARATIVE COSTS OF NUTRITIVE INGREDIENTS IN DIFFERENT FOOD MATERIALS.

A subject that has received but little attention in this country, though it has become a vital one in Europe, and is becoming so with us, is the cost of the nutritive material of our foods. The relative cheapness or dearness of different foods must be judged by comparing, not the prices per pound, but the costs of the actual

nutrients. In making such comparisons, the cost may be assumed to fall, not upon the inedible portions and the water, but solely upon the three classes of nutrients, the protein, fats, and carbohydrates. The relative physiological values of the nutrients in different foods depend upon (1) their digestibility and (2) their functions and the proportions in which they can replace each other in nutrition. An accurate physiological valuation is, in the present state of our knowledge, at least, impracticable. The pecuniary costs of the nutrients are, however, more nearly capable of approximation.

Various methods have been proposed for computing the relative pecuniary costs of the nutrients of foods, none of which, however, are entirely beyond criticism. The following, based upon German estimates of the relative costs of protein fats and carbohydrates, is perhaps as satisfactory as any.

From extended comparisons of the composition and market prices of the more important animal and vegetable food materials, such as meats, fish, flour, etc., those which serve for nourishment and not as luxuries and form the bulk of the food of the people, it has been estimated that a pound of protein costs, on the average, five times as much, and a pound of fats three times as much, as a pound of carbohydrates; that, in other words, these three classes of nutrients stand related to each other, in respect to cost, in the following proportions:

Assumed ratios of costs in staple foods.	Protein, . .	5
	Fats, . .	3
	Carbohydrates, .	1

Suppose a pound of beef of average fatness to cost 25 cents, and to contain 25 per cent. of inedible matters, bone, etc., 45 per cent. of water, and 30 per cent. of nutritive substance, upon which latter—the bone and water being assumed to be without nutritive value—the whole cost comes. The 30 per cent. or $\frac{30}{100}$ pounds of nutritive substance thus costs 25 cents, or at the rate of $83\frac{1}{2}$ cents per pound. If now we leave out of account the minute quantities of carbohydrates and the mineral matters, the whole cost will fall upon the protein and fats. Assuming these to cost in the ratio of 5 : 3 and the amounts in the meat to be: protein $14\frac{1}{4}$ per cent., and fats 15 per cent., an easy computation will show the protein to cost 107.7 cents, and the fats 64.6 cents per pound. Proof :

$14\frac{25}{100}$ pound of protein at 107.7 cents = 15.3 cents. $\frac{15}{100}$ pounds of fats at 64.6 cents = 9.7 cents. 15.3 cents + 9.7 cents = 25 cents, the cost of the pound of meat which contained the given amounts of protein and fats.

Of the different nutrients, protein is physiologically the most important as it is pecuniarily the most expensive. For these reasons the cost of protein in different food materials may be used as a means of comparing their relative cheapness or dearness, as is done in the following table. The figures represent the ordinary prices per pound and the corresponding costs of protein, in specimens of food materials obtained in New York and Middletown, Conn., markets. Though the number of specimens is too small for reliable averages, the figures, taken together, doubtless give a tolerably fair idea of the relative costliness of the nutrients in the different classes of foods. It will of course be understood that the computations make allowance for the costs of the other nutrients, the fats and the carbohydrates, though for the sake of brevity the latter are omitted from the table.

TABLE VI.

COMPARATIVE COSTS OF PROTEIN IN FISH AND OTHER ANIMAL AND VEGETABLE FOODS.

FOODS.	Ordinary prices per pound.	Cost of protein per pound.
	Cents.	Cents.
Beef, sirloin, medium fatness,..................	25	108
Beef, sirloin, at lower price,....................	20	86
Beef, round, rather lean,.......................	18	70
Beef, round, rather lean, lower price,..........	16	62
Beef, corned, lean,.............................	18	56
Beef, flank,* very fat,.........................	15	36
Mutton, leg,....................................	22	107
Mutton, side, medium fatness,...................	20	59
Pork,* very fat,................................	16	30
Smoked ham,.....................................	18	48
Milk, 8 cents per quart,........................	4	61
Cheese, whole milk,.............................	18	38
Cheese, skimmed milk,...........................	8	19
Salmon, early in season,........................	100	572
Salmon, when plenty,............................	30	172
Shad,...	12	98
Shad, when abundant,............................	8	65
Bluefish,.......................................	10	98
Haddock,..	7	94
Halibut,..	15	87
Mackerel,.......................................	10	80
Mackerel, when abundant,........................	5	40
Cod,..	8	67
Cod, when plenty,...............................	6	50
Alewife,..	3	19
Canned salmon,..................................	20	70
Salt mackerel,..................................	12.5	46
Salt cod,.......................................	7	38
Salt cod, lower,................................	6	33
Oysters,† 35 cents per quart,...................	17.5	220
Oysters, 50 cents per quart, choice,............	25	312
Lobsters,.......................................	12	209
Wheat flour, best,..............................	4.5	17
Wheat bread,....................................	8	38
Indian corn (maize) meal,.......................	3	12
Oatmeal,..	5	15
Beans,..	5	14
Potatoes,* 50 cents per bushel,.................	0.8	14
Potatoes, 100 cents per bushel,.................	1.7	28

* Contains very little protein. † Shell contents.

Thus the nutrients of vegetable foods are, in general, much less costly than in animal foods. The animal foods have, however, the advantage of containing a larger proportion of protein and fats, and the protein, at least, in more digestible forms.

Among the animal foods, those which rank as delicacies are the costliest. By the above calculations, the protein in the oysters costs from two to three dollars, and, in salmon, rises to nearly six dollars per pound. In beef, mutton, and pork, it varies from 108 to 48 cents; in shad, blue-fish, haddock, and halibut, the range is about the the same; while in cod and mackerel, fresh and salted, it ranges from 67 to as low as 33 cents per pound. Salt cod and salt mackerel are nearly always, fresh cod and mackerel often, and even the choicer fish, as blue-fish and shad, when abundant, cheaper sources of protein than any but the inferior kinds of meat. Among meats, pork is the cheapest; but salt pork or bacon has the disadvantage of containing very little protein.

It is well worth the noting that oat meal is one of the cheapest foods that we have; that is, it furnishes more nutritive material, in proportion to the cost, than almost any other. Corn meal is indeed cheaper, but the oat meal has this great advantage over corn meal and wheat flour, that it has more protein. Of course, if we are to eat large quantities of lean meat—and most of us, I think, eat more than is best for our health, saying nothing of our purses, the extra protein in the oat meal is of little consequence to us. But if one wishes to economize in his food, oat meal—rightly cooked—affords an excellent material therefor.

The above method of computing the relative expensiveness of different kinds of food materials is, as I have said, open to the objection that it is based upon a certain assumed ratio of relative costs of protein, fats, and carbohydrates, which may be right or wrong in a given case. A method free from these objections consists in computing how much of the several nutrients may be obtained for a given sum, for instance, 25 cents, in different food materials.

Suppose that we are buying sirloin of beef at 25 cents per pound. Then, for our 25 cents, we shall of course, get one pound. If, now, the meat we buy, has the composition of the specimen of which the analysis was given in Table II, we should have

In 1 pound of sirloin of beef at 25 cts. per pound.

14.3 one-hundredths of a pound of protein.

15 one-hundredths of a pound of fat.

If, however, we could buy the same sirloin at 20 cents a pound, we should get a pound and a quarter for 25 cents, and should then have

In 1¼ pounds of sirloin of beef at 20 cts. per pound:

18 one-hundredths of a pound of protein.

19 one-hundredths of a pound of fat.

The figures in the following table show the quantities of nutrients obtained for 25 cents in a number of the food materials of Tables I and V, at the prices stated opposite each. At the bottom are quantities sufficient for a day's ration for an ordinary man.

TABLE VII.

COMPARATIVE EXPENSIVENESS OF FOODS.—AMOUNTS OF ACTUAL NUTRIENTS OBTAINED FOR 25 CENTS IN DIFFERENT FOOD MATERIALS.

FOOD MATERIALS.	Prices per Pound.	Quantities obtained for 25 cents. Pounds and hundredths of a pound.			
		Food Materials.	Actual Nutrients in Food Materials.		
			Protein.	Fats.	Carbohydrates.
Beef, sirloin, medium fatness,	25 cts.	1.00 lbs.	.14 lbs.	.15 lbs.	... lbs.
Beef, sirloin, at lower price,	20 "	1.25 "	.18 "	.19 "	... "
Beef, round,	18 "	1.39 "	.29 "	.11 "	... "
Mutton, leg	22 "	1.14 "	.14 "	.33 "	... "
Mutton, side,	20 "	1.25 "	.17 "	.29 "	... "
Pork (salted) fat,	16 "	1.56 "	.04 "	1.19 "	... "
Milk, at 8 cents per quart,	4 "	6.25 "	.21 "	.23 "	.30 "
Cheese, whole milk,	18 "	1.39 "	.38 "	.49 "	.03 "
Cheese, skimmed milk,	8 "	3 13 "	1.20 "	.21 "	.28 "
Salmon, early in season,	100 "	.25 "	.04 "	.02 "	... "
Salmon, when plenty,	30 "	.83 "	.12 "	.07 "	... "
Shad,	12 "	2.08 "	.19 "	.10 "	... "
Shad, when abundant,	8 "	3.13 "	.29 "	.15 "	... "
Blue-fish,	10 "	2.50 "	.25 "	.02 "	... "
Mackerel,	10 "	2.50 "	.25 "	.10 "	... "
Mackerel, when plenty,	5 "	5.00 "	.51 "	.20 "	... "
Cod,	8 "	3.13 "	.34 "	.01 "	... "
Cod, when plenty,	6 "	4.17 "	.46 "	.01 "	... "
Salt Mackerel,	12.5 "	2 00 "	.34 "	.35 "	... "
Salt Cod,	7 "	3.57 "	.57 "	.01 "	... "
Oysters, at 35 cents per quart,	17.5 "	1.42 "	.09 "	.02 "	.06 "
Oysters, at 50 cents per quart,	25 "	1.00 "	.06 "	.02 "	.04 "
Butter,	30 "	.83 "	... "	.73 "	... "
Wheat flour, best,	4.5 "	5.55 "	.62 "	.07 "	4.15 "
Wheat bread,	8 "	3.12 "	.49 "	.11 "	3.03 "
Indian meal,	3 "	8.33 "	.70 "	.29 "	5.91 "
Oat meal,	5 "	5 00 "	.76 "	.36 "	3.36 "
Beans,	5 "	5.00 "	1.16 "	.11 "	2 69 "
Potatoes, at 50 cents per bushel,	.85"	29.41 "	.59 "	.06 "	6.06 "
Potatoes, at $1.00 per bushel,	1.7 "	14.71 "	.29 "	.03 "	3.03 "
Daily ration for ordinary man at moderate work,			.26 lbs.	.12 lbs.	1.10 lbs.

I confess that when I first saw the figures of Tables VI and VII, which were worked out, at my suggestion, by an assistant, who happened, like myself, to be curious to see what our analyses would indicate as to the relative expensiveness of different food materials, I was not a little impressed by the very forcible way in which they set forth the facts. Of course these figures do not show exactly what foods are most economical for any given person. They simply show what ones are the cheapest, i. e., furnish the most nutritive material for the least money. For we must remember that the economy of using a given kind of food depends not only upon its cheapness, but also upon its fitness for supplying the needs of the user.

Another interesting matter in this connection is the great difference between the costs of our foods and their values for nourishing our bodies. This difference has a very simple explanation in the fact that the taste and the palatableness of our foods is one of the important factors of their price. In other words, we pay for many of our foods according to their agreeableness to our palates rather than their values for nourishing our bodies. At the same time it is interesting to note that the prices of the materials that make up the bulk of the food of the people seem to run more or less parallel with their actual nutritive values. Here, as elsewhere, the resultant of the general experience of mankind has led slowly and blindly, but none the less surely, to the same general result to which accurate research more understandingly and quickly guides us.

These considerations lead us to still another interesting fact. The poorer classes of people and communities almost universally select those foods which chemical analysis shows to supply the actual nutrients at the lowest cost. But, unfortunately the proportions of the nutrients in their dietaries are often very defective.

Thus, in portions of India and China, rice; in Northern Italy, maize meal; in certain districts of Germany, and in some regions and seasons in Ireland, potatoes; and among the poor whites of the Southern United States, maize meal and bacon make a large part, and, in some cases, almost the sole food of the people. These foods supply the nutrients in the cheapest forms, but are all deficient in protein. The people who live upon them are ill nourished, and suffer physically, intellectually, and morally thereby.

On the other hand, the Scotchman, shrewd in his diet as his dealings, finds a most economical supply of protein in oat meal, haddock and herring, and the rural inhabitants of New England supplement the fat of their pork with protein of beans and the carbo-hydrates of potatoes; maize and wheat flour with the protein of codfish and mackerel, and while subsisting largely upon such frugal but rational diets, are well nourished, physically strong, and distinguished for their intellectual and moral force.